Market Trends, Opportunities and Latest Process Innovation in Vacuum Metallization – Introducing BOBST AluBond® Technology

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Presentation outline

- Introduction & background
  - Global market trends in vacuum metallizing
  - Metal adhesion evaluation
- AluBond® process & performance
  - Adhesion – EAA peel test
  - Adhesion – Laminate bond strength
  - Barrier performance
  - Metallizing defects – Optical microscopy
- Dyne level and dyne level retention
- Summary and conclusions
Introduction & background
Global market trends in vacuum metallization
The challenges....

1. Higher process performance
   - High metal adhesion (examples: >2N/15mm PET/OPP, Increased metal adhesion on CPP & PE structures)
   - High barrier metallization for increased shelf life (Al foil replacement, layer reduction, substrate down-gauging)
   - Higher dyne level, better dyne level retention (metallized polyolefin substrates)

2. Cost reduction (commodity)
   - Down-gauging of substrates ⇒ Temperature/heat load management
   - Metallization of more heat-sensitive substrates
   - Increased output/ productivity/ reliability & reduced production cost
   - Wide web metallization (movement: toll ⇒ convertor ⇒ film producer’)

3. Alternative & new process technologies (added value/ niche applications)
   - Transparent inorganic barrier (SiOₓ & AlOₓ higher barrier single layer (dry and wet) and conversion solutions)
   - Selective or partial Metallization (decorative, functional, security + barrier requirements)
Higher process performance

• High barrier – DarkNight® & AluBond® process
• High adhesion – AluBond® process
• Defect reduction – Hawkeye pinhole detector (in-line defect detection & opacity control)
• Higher dyne and dyne level retention – AluBond® process or plasma post treatment

Cost reduction

• Metallization of more heat sensitive substrates – K5 VISION & K5 EXPERT
• Metallization of down gauged materials – K5 VISION & K5 EXPERT
• Increased output/ productivity/ reliability – K5 VISION & K5 EXPERT/ K5 Wide Web

Alternative & new process technologies (added value/ niche applications)

• Transparent inorganic barrier – SiOₓ (PECVD), AlOₓ (reactive PVD) & AlOₓ conversion solutions
• Selective or partial metallisation – SelectMet® process
Global market trends in vacuum metallization
Market available solutions for improving metal adhesion

Non-vacuum techniques
• *Chemical treatment/coating*
  • Cost Implications for the convertor
  • Production/ processability implications for the film producers
  • Potential detrimental barrier effects when combing with dry vacuum technology
• *Atmospheric plasma/ corona treatment*
  • Treatment consistency, uniformity & decay over time
• *Flame treatment*
  • Thermal implications (heat-sensitive & down-gauged materials)

In-vacuum techniques
• *Plasma treatment*
  • Limited adhesion (typically 1 – 2 N/(15 mm) for PET)
  • Special higher power or multiple treaters (levels of 2 – 3 N/(15 mm) for PET)
  • Limitation: Reliability/ consistency (process stability/ arcing/ electrode cleaning)
• New *BOBST AluBond®* technology
Metal adhesion evaluation
Techniques currently used in industry

**Tape test** (AIMCAL TP-104-87)
- Instant result, no sample preparation
- Qualitative test method (pass/fail) ⇒ main limitation

**EAA seal & peel test** (AIMCAL TP-105-92, EMA seal test)
- Quantitative test method
- Sample preparation & specific equipment required
- Intrinsic strength of EAA film ⇒ main limitation

**Laminate bond strength** (ASTM F88, ISO 11339)
- Quantitative test method
- Time consuming & specific equipment required
- More representative of actual packaging application
Metal adhesion evaluation
Interpreting and using quantitative adhesion results correctly

EAA peel test & laminate bond strength
- Different test setup ⇒ different results (peel speed, peel angle, sealant film thickness etc.)
- Test graph – Correct data extraction
- Failure mode – It’s not just a number …

Initial peel
(not used for average peel force)

180° peel test

Actual peel – metal removal
(used for average peel force)

Picture source: ASTM F88/F88M
AluBond® process & performance
What is BOBST AluBond® Technology?

AluBond® – A hybrid coating technology
- Vastly improved anchoring properties to the base substrate
- Tailored coating stoichiometry (reactants (AluBond®) + products (Al)) created via a uniquely designed coating gradient

AluBond® – Process performance
- Improved metal adhesion between the metallised layer and the underlying base substrate to levels which conventional ‘plasma’ based systems have been unable to achieve (on barrier and sealant webs)
- Enhanced dyne level & dyne retention
- Barrier improvement obtained on all sealant webs tested
**AluBond® process performance**

**Metal adhesion – EAA peel test**

**EAA peel test – *Metallized PET***

- Sealing: 105 °C, 4 bar, 20 s, speed: 50 mm/min

<table>
<thead>
<tr>
<th>Structure</th>
<th>Description</th>
<th>Peel force N/(15 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PET/Al 12 µm</td>
<td>Metal only</td>
<td>0.08 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>Low dosage plasma</td>
<td>0.38 ± 0.30</td>
</tr>
<tr>
<td>Low dosage</td>
<td>Low dosage plasma + <em>AluBond®</em></td>
<td>6.12 ± 0.21</td>
</tr>
<tr>
<td>Low dosage</td>
<td><em>AluBond®</em></td>
<td>6.12 ± 0.28</td>
</tr>
</tbody>
</table>

- No metal removal
- EAA elongation, break or delamination

Diagram:
- EAA-film
- Coated film
- Peel direction
- Metal plate
- Double-sided adhesive tape
- Peel-off angle 180°
- Coating layer on EAA-film
- EMA (European Metallizers Association) test procedure for metal adhesion (seal test)
**AluBond® process performance**

**Metal adhesion – EAA peel test**

**EAA peel test – *Metallized BOPP and CPP***

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<tr>
<th>Structure</th>
<th>Description</th>
<th>Peel force N/(15 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOPP/Al 50 µm</td>
<td>Metal only</td>
<td>1.01 ± 0.23</td>
</tr>
<tr>
<td></td>
<td><em>AluBond®</em></td>
<td>5.91 ± 0.25</td>
</tr>
<tr>
<td>BOPP/Al 20 µm</td>
<td>Metal only</td>
<td>0.52 ± 0.14</td>
</tr>
<tr>
<td></td>
<td><em>AluBond®</em></td>
<td>4.47 ± 0.33</td>
</tr>
<tr>
<td>CPP/Al 25 µm</td>
<td>Metal only</td>
<td>0.89 ± 0.22</td>
</tr>
<tr>
<td></td>
<td><em>AluBond®</em></td>
<td>3.12 ± 0.08</td>
</tr>
</tbody>
</table>

- **Non-AluBond®**
  - Full metal removal at **low peel force**
  - Peeled-off EAA is shiny for non-AluBond® and dull for AluBond®

- **AluBond®**
  - Partial/full metal removal at **high peel force**
  - ‘shiny’
  - ‘dull’
AluBond® process performance
Metal adhesion – FTIR analysis

EAA peel test – *Metallized BOPP and CPP*

AluBond® peel test sample shows clear PP and EAA peaks in FTIR analysis

⇒ BOPP/CPP skin layer peeled off along with AluBond® metallization layer
AluBond® process performance
Metal adhesion – Cross-web uniformity

EAA peel test – *AluBond® Metallized BOPP*

- Adhesion uniformity across web width & length
- Non-AluBond® adhesion: 0.52 N/(15 mm)
- 20 µm BOPP, 2.2 OD

Adhesion Levels – Position from pump side of film

<table>
<thead>
<tr>
<th>Position (mm)</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
<th>700</th>
<th>800</th>
<th>900</th>
<th>1000</th>
<th>1100</th>
<th>1200</th>
<th>1300</th>
<th>1400</th>
<th>1500</th>
<th>1600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesion N/(15 mm)</td>
<td>3.92</td>
<td>4.23</td>
<td>4.00</td>
<td>4.40</td>
<td>4.78</td>
<td>4.13</td>
<td>4.64</td>
<td>4.71</td>
<td>4.80</td>
<td>4.29</td>
<td>4.54</td>
<td>4.64</td>
<td>4.45</td>
<td>4.56</td>
<td>4.75</td>
<td>4.70</td>
</tr>
</tbody>
</table>
| Failure mode | *Partial metal and B OPP skin layer removal*

⇒ *AluBond®* adhesion shows very good cross-web uniformity
AluBond® process performance

Metal adhesion – Adjustment of AluBond® adhesion level

EAA peel test – Metallized CPP (example)

- AluBond® adhesion level can be tuned to certain degree
- No linear relationship
- Significant step change typical for AluBond® level 5
AluBond® process performance
Metal adhesion – Retention of AluBond® adhesion level

- EAA peel test investigations
- AluBond® adhesion level maintained over extended storage times
AluBond® process performance
Metal adhesion – Laminate bond strength

Laminate bond strength – *Metallized PET and BOPP*

- Laboratory lamination
- Solvent based 2-component PU adhesive
- 70 µm CPP secondary web (duplex laminate)
- 180° supported peel test at 50 mm/min
- 90° unsupported peel test at 100 mm/min

Picture source: ISO 11339
AluBond® process performance
Metal adhesion – Laminate bond strength

Laminate bond strength – *Metallized PET and BOPP*

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<tr>
<td>PET/Al 12 µm</td>
<td>180º supported</td>
<td>Metal only</td>
<td>3.03 ± 0.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>AluBond®</em></td>
<td>4.48 ± 0.49</td>
</tr>
<tr>
<td></td>
<td>90º unsupported</td>
<td>Metal only</td>
<td>2.19 ± 0.29</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>AluBond®</em></td>
<td>3.55 ± 0.34</td>
</tr>
<tr>
<td>BOPP/Al 20 µm</td>
<td>180º supported</td>
<td>Metal only</td>
<td>2.54 ± 0.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>AluBond®</em></td>
<td>5.34 ± 0.22</td>
</tr>
<tr>
<td></td>
<td>90º unsupported</td>
<td>Metal only</td>
<td>2.69 ± 0.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>AluBond®</em></td>
<td>3.22 ± 0.27</td>
</tr>
</tbody>
</table>

⇒ Full metal removal for non-AluBond®
⇒ Partial metal removal for AluBond®
⇒ PET/BOPP film break for Alubond® in 90º unsupported T-peel test

**AluBond®**
BOPP
Partial metal removal & CPP delamination

**Non-AluBond®**
BOPP
Full metal removal
AluBond® process performance
Metal adhesion – Laminate bond strength

Laminate bond strength – *Metallized PET*
- Triplex laminate PETprint / metPET / CPP

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<tr>
<td>PET/Al</td>
<td>180°</td>
<td>Metal only</td>
<td>0.70 ± 0.22</td>
</tr>
<tr>
<td></td>
<td>supported</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PET/Al</td>
<td>90°</td>
<td>Metal only</td>
<td>0.51 ± 0.12</td>
</tr>
<tr>
<td></td>
<td>unsupported</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**AluBond®**
Very limited metal removal & delamination/break of printed PET

Non-AluBond®
> 90 % metal removal

![Diagram showing laminate bond strength](image)
AluBond® process performance

Barrier properties – Metallized BOPP

- Standard grade BOPP film
- 20 µm thickness, 3 layer coex-structure
- Corona treated

<table>
<thead>
<tr>
<th>Description</th>
<th>OD</th>
<th>OTR (cm³/(m² d))</th>
<th>WVTR (g/(m² d))</th>
<th>Adhesion (EAA peel test) (N/(15 mm))</th>
</tr>
</thead>
<tbody>
<tr>
<td>AluBond®</td>
<td>2.5</td>
<td>8.45 ± 0.08</td>
<td>0.06 ± 0.01</td>
<td>4.3 ± 0.2</td>
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<tr>
<td>AluBond®</td>
<td>2.8</td>
<td>5.12 ± 0.34</td>
<td>0.03 ± 0.00</td>
<td>4.1 ± 0.2</td>
</tr>
<tr>
<td>AluBond®</td>
<td>3.3</td>
<td>4.82 ± 0.57</td>
<td>0.03 ± 0.00</td>
<td>3.4 ± 0.5</td>
</tr>
<tr>
<td>Standard metal</td>
<td>2.5</td>
<td>50</td>
<td>0.4</td>
<td>1.1</td>
</tr>
</tbody>
</table>

*OTR 23 °C, 50% RH
**WVTR 37.8 °C, 90% RH

⇒ Significantly enhanced barrier performance for Alubond® metallized BOPP
AluBond® process performance
Barrier properties

Barrier properties – *Metallized CPP*
- Standard grade CPP film
- 25 µm thickness, 3 layer coex-structure
- Corona treated

<table>
<thead>
<tr>
<th>Description</th>
<th>OD</th>
<th>OTR</th>
<th>WVTR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>cm³/(m² d)</td>
<td>g/(m² d)</td>
</tr>
<tr>
<td>AluBond®</td>
<td>2.3</td>
<td>3.17 ± 0.42</td>
<td>0.05 ± 0.00</td>
</tr>
<tr>
<td>AluBond®</td>
<td>2.7</td>
<td>2.60 ± 0.09</td>
<td>0.04 ± 0.00</td>
</tr>
<tr>
<td>AluBond®</td>
<td>3.3</td>
<td>2.48 ± 0.21</td>
<td>0.03 ± 0.00</td>
</tr>
<tr>
<td>Standard metal</td>
<td>2.5</td>
<td>50</td>
<td>0.15</td>
</tr>
<tr>
<td>Datasheet information</td>
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</tr>
</tbody>
</table>

*Significantly enhanced barrier performance for Alubond® metallized CPP*

*OTR 23 °C, 50% RH
**WVTR 37.8 °C, 90% RH
AluBond® process performance
Barrier properties

Barrier properties – *Metallized BOPP*
- WVTR behaviour during barrier measurement (37.8 °C, 90 % RH)

⇒ AluBond® shows *better moisture barrier* properties and *RH stability/corrosion resistance*
AluBond® process performance
Metallizing defects – Optical microscopy

Metallizing defects – *Metallized PET*

⇒ AluBond® shows a reduction in/elimination of *starry-night type defects*
AluBond® process performance
Dyne level and dyne level retention

Dyne level retention – *Metallized BOPP and CPP*

 ⇒ AluBond® metallized films show improved dyne level and better dyne level retention
Summary & conclusions

AluBond® delivers:

• Considerably higher *metal adhesion* compared to standard metallised film (EAA peel test, duplex & triplex laminates)
• Enhanced *barrier performance* for polyolefin substrates
• Enhanced *corrosion resistance* of aluminium layer
• Reduction in *metallizing defects*
• Higher *dyne level* and better *dyne level retention*

⇒ AluBond® addresses & satisfies current market trends for higher performance packaging materials
THANK YOU